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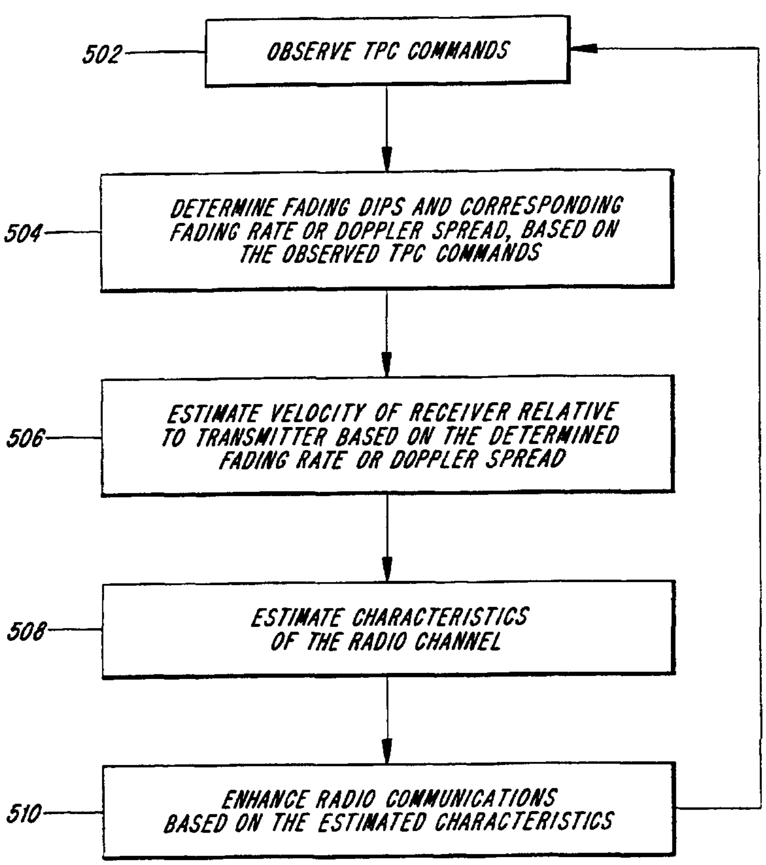
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KR (utility model), KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

[Continued on next page]

(54) Title: RELATIVE VELOCITY ESTIMATION USING TPC-COMMANDS



(57) Abstract: In a system having a transmitter and a receiver that communicate over a radio channel and in which signal transmission power of the transmitter is adjusted to compensate for fading dips in the channel, the Rayleigh fading rate of the radio channel, and thus the relative velocity between the transmitter and the receiver, are estimated by effectively observing the adjustments or fluctuations in signal transmission power or amplitude of the transmitter. In accordance with an exemplary embodiment of the invention, this is done by observing TPC (Transmission Power Control) commands that cause the transmitter to adjust its signal transmission power to combat Rayleigh fading, i.e., fading dips, in the radio channel. Since the TPC commands cause the transmitter to vary its signal transmission power to compensate for the fading dips, the fading dips and thus the fading rate and the relative velocity between the transmitter and the receiver can be determined by observing the signal transmission power fluctuations represented by the TPC commands.

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RELATIVE VELOCITY ESTIMATION USING TPC-COMMANDS

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to wireless telecommunications, and in particular to estimating the velocity of a mobile station relative to a transmitter in a mobile communications system.

Background Art

In mobile communication systems, it is often necessary to accurately estimate or model the radio channel in order to enhance performance of a receiver receiving signals over the radio channel.

FIG. 1 illustrates an exemplary radio channel that is known in the art. In particular, a transmitter 102 transmits signals via a radio channel 104, which is affected by AWGN (Additive White Gaussian Noise) as represented by element 106. The signal is then received at a receiver 108.

Radio channels are often subject to multipath propogation, which arises when a path between a transmitter and a receiver includes reflections from large objects, so that rays of the transmission signal from the transmitter travel along different paths having different lengths, before meeting at the receiver. Thus, when the rays of the signal meet there are phase differences between them because of the different path lengths. This can give rise to Rayleigh fading, where the rays or echoes of the transmission signal constructively or destructively combine, depending on their phases. Thus, the combined signal received at the receiver appears to vary randomly in amplitude and phase, due to being composed of the many smaller rays or echoes of the transmission signal that traveled along different paths on their way to the receiver. Thus, even when transmitter outputs a transmission signal with a constant power or amplitude, the amplitude or power of the transmission signal at the receiver can vary due to Rayleigh fading.

The combined signal received by the receiver is typically modeled or represented as having a Rayleigh Probability Distribution, which is defined as:

$$P(r) = \frac{re^{-r^2/2s^2}}{S^2}$$

In other words, the Rayleigh Distribution describes a distribution of signal components in a Rayleigh Fading Channel within an envelope about an RMS value of a signal transmitted from a transmitter to a receiver, when the line-of-sight path between the receiver and the transmitter is obstructed so that the signal transmitted by the transmitter reaches the receiver in a multipath fashion, with different rays or components of the signal reflecting along different paths to the receiver. The Rayleigh Distribution describes the envelope because, due to the arrival of numerous out-of-phase multipath components or rays, the in-phase and quadrature components of the signal are Gaussian in nature. Hence, the signal envelope, which is the square root of the sum of the squares of the in-phase and quadrature components, follows a Rayleigh Distribution.

Whether the rays of the transmission signal from the transmitter combine constructively or destructively at the receiver, depends on the particular locations of the receiver and transmitter and the obstructive/reflective objects in the environment surrounding them. Thus, if the receiver changes position relative to the transmitter and the environment, it can move through positions where the rays combine differently. In other words, as the receiver moves, the rays will combine at the receiver constructively and then destructively in an alternating fashion, so that the receiver experiences a series of "fading dips" where the amplitude of the received signal periodically dips down and then returns to its former level. The frequency of these fading dips, or in other words the number of fading dips per unit time, is commonly referred to as the "fading rate" of the radio channel.

The fading rate corresponds to the velocity of the receiver relative to the transmitter, so that as the velocity of the receiver increases, so does the fading rate. As it turns out, the fading

rate is equivalent to the "Doppler spread" of the Rayleigh fading radio channel, which is defined as:

$$F_d = \frac{2 \cdot V \cdot F_c}{c}$$

where F_d = Doppler spread,

V = velocity of the receiver relative to the transmitter,

F_c = frequency of the transmission signal from the transmitter, and

c = the speed of light (3 x 10^8 meters/second).

For example, if the velocity of the receiver is 50 kilometers/hour and the transmission signal frequency is 2 Ghz, the Doppler spread will be about 185 hertz. Thus, the fading rate will be 185 hertz, which means that the amplitude of the transmission signal at the receiver will dip, or cyclically fade in amplitude and then recover, 185 times per second. Conversely, if the transmission signal frequency and the fading rate are known, this equation can be used to determine the relative velocity of the receiver.

The relative velocity between the receiver and the transmitter is proportional to a bandwidth of the Rayleigh distribution, which in turn is related to the properties of the radio channel, such as the radio channel's second moment statistical properties. If the properties of the radio channel are known, commutation or communication between the transmitter and the receiver can be significantly improved. In other words, the relative velocity between the receiver and the transmitter determines or reflects properties of the radio channel that are useful to enhance communication between the transmitter and the receiver. Consequently, it is important to accurately determine the relative velocity between the receiver and the transmitter, *e.g.*, between a Mobile Station (MS) and a Base Station (BS) in a mobile communications network. The relative velocity between the receiver and the transmitter is usually estimated by studying the fading properties of the radio channel as seen by the receiver, for example in accordance with the Doppler spread equation described above.

Due to the high chip rate in mobile communications systems that use CDMA (Code Division Multiple Access), receivers in such systems are usually equipped with a power control to reduce or combat the effects of fading dips in the radio channel. Control of the

power of the signal broadcast by the transmitter is typically based on the receiver's estimation of the SIR (Signal to Interference Ratio). The SIR is typically estimated using pilot techniques such as pilot signals or channels, data, or a combination of pilot techniques and data. The receiver uses the estimate of the SIR to inform or instruct the transmitter to reduce or increase the power with which it broadcasts signals to the receiver. In essence, the transmitter varies the signal broadcast power to compensate for Rayleigh fading. Thus, the power or amplitude of the broadcast signal at the transmitter is varied so that the power or amplitude of the broadcast signal from the transmitter will be effectively constant at the receiver, thereby maintaining a constant SIR at the receiver.

FIG. 2 shows an exemplary procedure known in the art, wherein as shown in step 202, the SIR is estimated using data and/or pilot techniques. From step 202 control flows to step 204, where the SIR is compared against a reference. From step 204 control flows to step 206, where TPC-commands are formed based on the comparison in step 204, and then sent to the transmitter to inform the transmitter how it should change the power or amplitude of the signal it is transmitting to the receiver.

Communications between the receiver and the transmitter (*e.g.*, the mobile station and the base station) relating to controlling signal power transmitted from the transmitter are usually performed using TPC commands.

FIG. 3 illustrates an exemplary structure of data transmitted in downlink from a network to a mobile station in a W-CDMA (Wideband - Code Division Multiple Access) system. In particular, a super frame 302 contains 72 frames such as the frame 304. Each of the frames contains 15 slots such as the slot 306. Each slot contains symbols, including pilot symbols and TPC symbols. The number of symbols of each kind, and the total number of all symbols in the slot, depends on the spreading factor used for the CDMA spreading. For example, each slot can contain a total of 20 symbols including 4 pilot symbols 308 and a single TPC symbol 310 as shown in slot 306.

The transmission power control rate applied to the transmitter limits the maximum fading rate which the transmitter can effectively compensate for. For example, in W-CDMA (Wideband - Code Division Multiple Access) where the power control rate is 1,500 hertz, fading dips can be effectively combated using TPC commands when the mobile station is moving with a velocity of less than 30 kilometers per hour. The power control typically operates most effectively to combat fade when the relative velocity is low with respect to the

power control rate. This is because the power control rate determines how quickly the transmitter can react and alter its broadcast power output to combat fading dips at the receiver, and the relative velocity between the receiver and the transmitter determines how quickly fading dips can occur at the receiver. As the relative velocity increases and therefore also the fade rate, the power control rate necessary to effectively combat the fade must also increase. In other words, a higher fading rate due to a greater relative velocity of the receiver can in theory be effectively combated using TPC commands if the power control rate is increased appropriately.

However, the relative velocity between the receiver and the transmitter is usually estimated by studying the fading properties of the radio channel as seen by the receiver. Accordingly, this technique for estimating the relative velocity is inaccurate when the TPC commands are effectively used to combat the Rayleigh fading seen by the receiver, because the compensation removes the fade seen by the receiver. In other words, inaccuracy of the velocity estimation increases with the effectiveness of the power control. When the velocity is low with respect to the power control rate, so that the power control effectively combats fade, the velocity estimation will be inaccurate.

Accordingly, a need exists to accurately estimate the relative velocity between a transmitter and a receiver such as a mobile station and a base station while simultaneously reducing or eliminating fade.

SUMMARY OF THE INVENTION

In accordance with exemplary embodiments of the invention, in a system that has a transmitter and a receiver that communicate over a radio channel, and that compensates for fade at the receiver, the Rayleigh fading rate or Doppler spread of the radio channel and thus the relative velocity between the transmitter and the receiver, are estimated by effectively observing fluctuations in signal power or amplitude that occur at the transmitter, instead of fluctuations in power or quality of a signal received at the receiver. This is done by observing the TPC commands, or the signal broadcast power changes represented by the TPC commands, sent by the receiver to the transmitter to cause the transmitter to adjust its signal transmission power so that the signal will have an effectively constant power level or signal quality when it is received by the receiver.

Since the pattern of TPC commands (or the power changes they represent) corresponds to fading dips in the channel, the TPC commands can be observed over a period

of time to determine how many fading dips occurred in the channel during that time. Consequently, the TPC commands, or the signal broadcast power changes indicated by the TPC commands, can be used to accurately estimate the fading rate, and also a relative velocity between the receiver and the transmitter using the Doppler spread technique described above with respect to the fading rate. Such estimations are appropriate when fading dips can be combated using TPC commands.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent to those skilled in the art from the following detailed description of preferred embodiments, when read in conjunction with the accompanying drawings. Like elements in the drawings have been designated by like reference numerals.

FIG. 1 shows radio communications in accordance with the prior art.

FIG. 2 shows an exemplary transmission power control procedure in accordance with the prior art.

FIG. 3 shows an exemplary structure of transmitted data in a downlink from a network to a mobile station in a W-CDMA (Wireless - Code Division Multiple Access) system.

FIG. 4 shows an example of a series of TPC commands corresponding to a fading dip.

FIG. 5 shows a process in accordance with exemplary embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with exemplary embodiments of the invention, in a system having a transmitter and a receiver that communicate over a radio channel and in which signal transmission power or amplitude emitted from the transmitter is adjusted to compensate for fading dips in the channel, the Rayleigh fading rate of the radio channel, and thus the relative velocity between the transmitter and the receiver, are estimated by effectively observing the adjustments or fluctuations in signal transmission power or amplitude of the transmitter.

The receiver controls and adjusts the transmission power of the transmitter to compensate for Rayleigh fading, *i.e.*, fading dips in the radio channel, so that a constant signal power or quality is provided at the receiver. For example, the receiver can send TPC (Transmission Power Control) commands to the transmitter to cause the transmitter to adjust its signal transmission power to combat the fading dips. Since the transmission power fluctuations correspond to and indicate the fading dips in the channel, the fading rate (fading dips per unit time) or Doppler spread can be determined by observing the TPC commands. In

turn, the fading rate or Doppler spread can be used to accurately estimate the relative velocity between the receiver and the transmitter using the Doppler spread technique described above with respect to the fading rate.

FIG. 4 shows an example of a series of TPC commands and a corresponding signal transmission power, indicating a fading dip. The X-axis is a time line with binary TPC commands ("u" = up, "d" = down) that cause the transmitter to increase or decrease its signal transmission power. The signal transmission power is indicated on the Y-axis. In this example, a slot structure such as that shown in FIG. 3 is used, wherein each slot that the receiver sends to the transmitter includes a TPC command. The frequency of TPC commands can be, for example, 1,500 hertz in a WCDMA system. Exemplary signal transmission power increments and other exemplary TPC command frequencies are well known in the art, and are therefore not described in further detail here.

As can be seen in time segment A, the TPC commands instruct the transmitter to effectively maintain a steady state signal transmission power. In time segment B, the overall effect is an increase in signal transmission power, and then in time segment C, the TPC commands issued by the receiver to the transmitter cause the transmitter to decrease the signal transmission power to the steady state level. In time segment D, the TPC commands instruct the transmitter to effectively maintain a steady state signal transmission power. Thus, FIG. 4 shows a single fading dip that occurred in the channel during a time period spanning the time segments B and C.

A bit of noise or variation in rate of signal power change during the dip can also be seen midway through time segment B, where one of the TPC commands causes the signal transmission power to decrease momentarily before the next TPC command causes the signal transmission power to continue increasing. In addition, it can be necessary to represent different rates of change in signal power using mixtures of "up" and "down" binary TPC commands. For example, a TPC sequence up-up-up-down-up-up-up-down represents a higher rate of change than a TPC series up-up-down-up-up-down. Those skilled in the art will recognize that well known signal processing techniques can be readily used to accurately discern fading dips corresponding to changes in signal transmission power over time, in spite of fluctuations in the signal transmission power that are caused by noise or other sources different from fading dips.

FIG. 5 illustrates a method of using TPC commands to estimate a relative velocity between a receiver and a transmitter in accordance with exemplary embodiments of the present invention. As indicated in step 502, TPC commands are first observed. From step 502, control flows to step 504, where a number of signal transmission power level fluctuations that correspond to fading dips in the radio channel between the transmitter and the receiver are identified based on the observed TPC commands. A time frame in which the identified fluctuations occur is also identified, to determine the rate or frequency of the identified fluctuations. This rate is an estimated fading rate or Doppler spread.

From step 504 control proceeds to step 506, where a velocity of the receiver relative to the transmitter is estimated based on the estimated fading rate or Doppler spread. In particular, the velocity can be estimated by plugging the estimated fading rate and the known carrier frequency of the signal transmitted by the transmitter into the Doppler spread equation set forth further above.

From step 506 control proceeds to step 508, where the estimated velocity of the receiver relative to the transmitter is used to estimate or characterize properties of the radio channel. From step 508 control proceeds to step 510, where the properties of the radio channel are then used to maintain or enhance the quality of communications between the receiver and the transmitter across the radio channel. From step 510, control proceeds to step 502 where the cycle repeats.

In accordance with an exemplary embodiment of the invention, observation and analysis of TPC commands to determine fading rate and relative velocity between a mobile station and a base station can take place within the mobile station. In accordance with another exemplary embodiment of the invention, observation and analysis of TPC commands to determine fading rate and relative velocity between a receiver and a transmitter can take place within the receiver. Alternatively, the analysis and determination can take place at any appropriate location or locations within, or connected to, the communication system.

Those skilled in the art will recognize that a mobile station can act both as a transmitter and as a receiver, and a base station can also act both as a transmitter and as a receiver, because communication between the mobile station and the base station is typically two-way. Accordingly, the principles described herein can apply variously and reciprocally to both mobile stations and base stations, as well as other transceivers.

Those skilled in the art will also appreciate that the present invention can be applied in systems having different or broader sets of available TPC commands, including for example TPC commands having a variety of available power increment magnitudes including zero.

Other mechanisms that indicate signal transmission power fluctuations at the transmitter that correspond to fading dips can also be used or observed to determine fading dips and fading rate in the radio channel, and a relative velocity between the receiver and the transmitter.

Those skilled in the art will further appreciate that the present invention can be embodied in other specific forms without departing from the spirit or essential characteristics thereof, and that the invention is not limited to the specific exemplary embodiments described herein. The presently disclosed exemplary embodiments are therefore considered in all respects to be illustrative and not restrictive. The scope of the invention is indicated by the appended claims rather than the foregoing description, and all changes that come within the meaning and range and equivalents thereof are intended to be embraced therein.

Claims:

1. A method for estimating a relative velocity between a transmitter and a receiver in a Rayleigh fading radio channel, comprising the steps of:

observing TPC (Transmission Power Control) commands that instruct the transmitter to vary its signal transmission power to combat Rayleigh fading in the radio channel;

estimating a Rayleigh fading rate of the radio channel based on the observed TPC commands; and

estimating a velocity of the receiver relative to the transmitter based on the estimated fading rate.

2. The method of claim 1, wherein the TPC commands are observed for a period of time and the step of estimating a Rayleigh fading rate comprises the steps of:

identifying series of TPC commands that correspond to fading dips in the channel; and

estimating the Rayleigh fading rate based on a number of fading dips indicated by the identified series of TPC commands that occurred during the period of time.

3. The method of claim 1, wherein the transmitter is a mobile station in a mobile communications network.

4. The method of claim 1, wherein the transmitter is a base station in a mobile communications network.

5. The method of claim 1, wherein the receiver is a mobile station in a mobile communications network.

6. The method of claim 1, wherein the receiver is a base station in a mobile communications network.

7.The method of claim 1, further comprising the steps of:

characterizing properties of the radio channel based on the estimated relative velocity; and

enhancing a quality of the radio communications between the transmitter and the receiver based on the characterized properties of the radio channel.

8. The method of claim 1, wherein the steps are performed by the receiver.

9. A method for estimating a relative velocity between a transmitter and a receiver in a Rayleigh fading radio channel, comprising the steps of:

observing fluctuations in signal transmission power emitted by the transmitter;

determining which of the fluctuations correspond to fading dips in the radio channel;

estimating a Rayleigh fading rate of the radio channel based on the determined fading dips; and

estimating a velocity of the receiver relative to the transmitter based on the estimated Rayleigh fading rate.

10. The method of claim 1, wherein the fluctuations are observed indirectly by observing TPC (Transmission Power Control) commands that instruct the transmitter to vary its signal transmission power.

Fig. 1
PRIOR ART

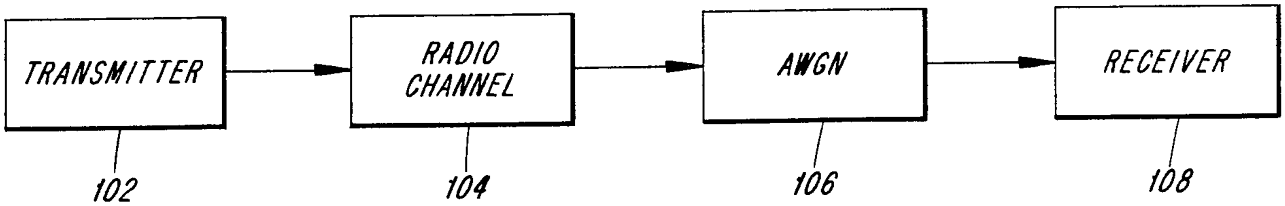


Fig. 2
PRIOR ART

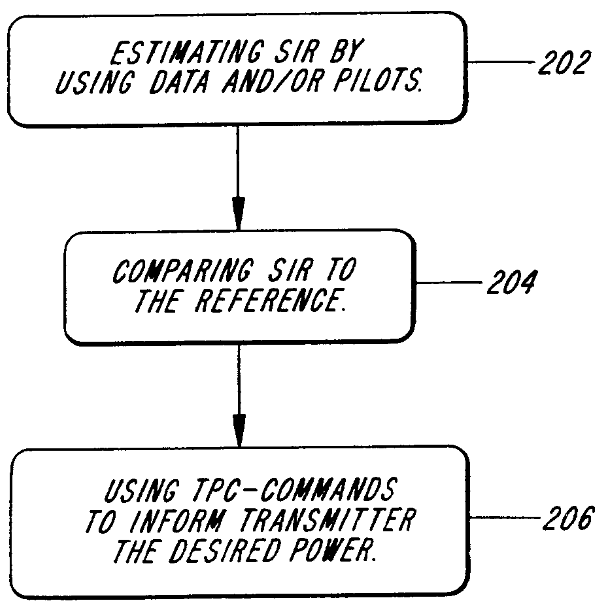


Fig. 3
PRIOR ART

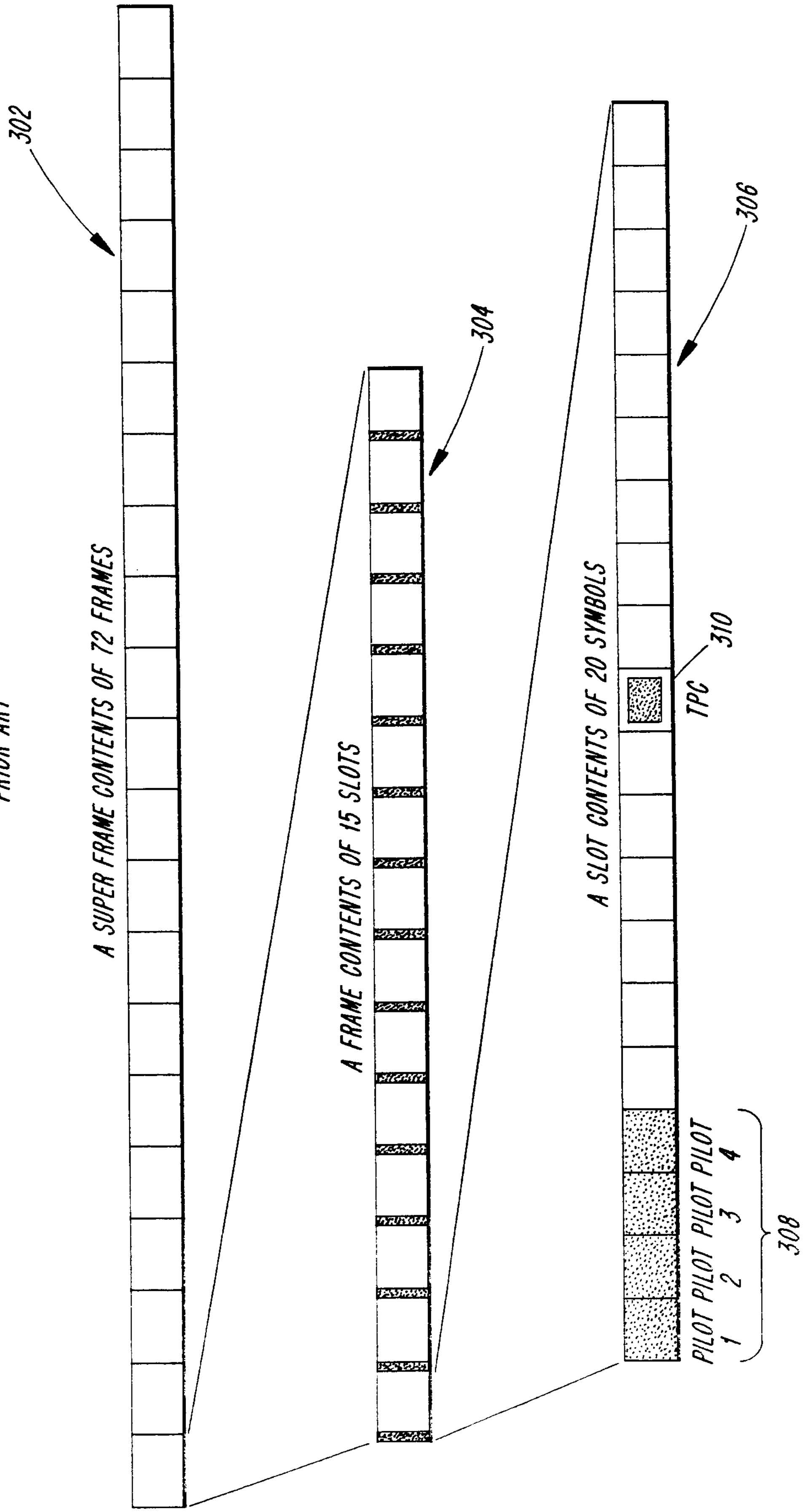


Fig. 4

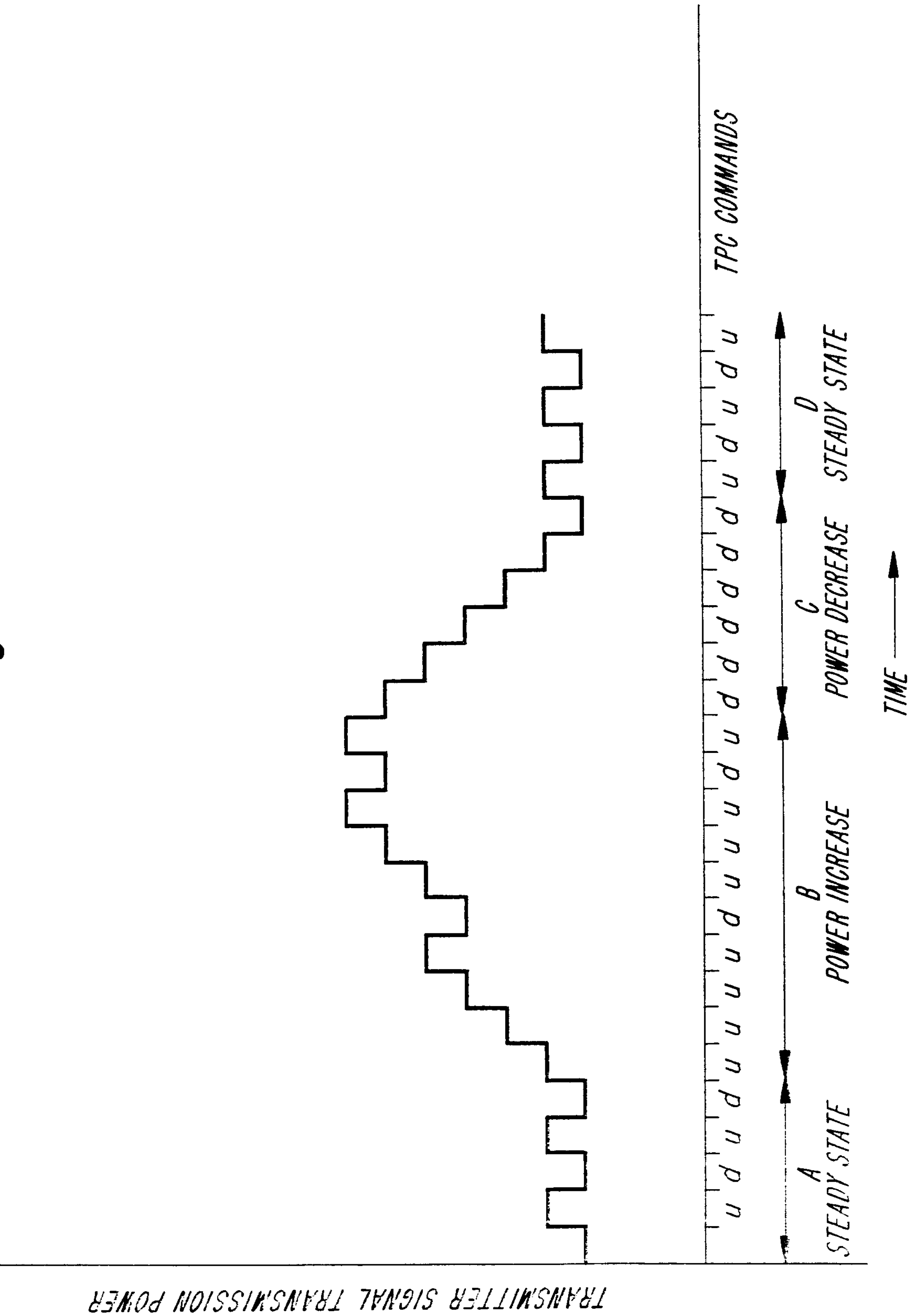
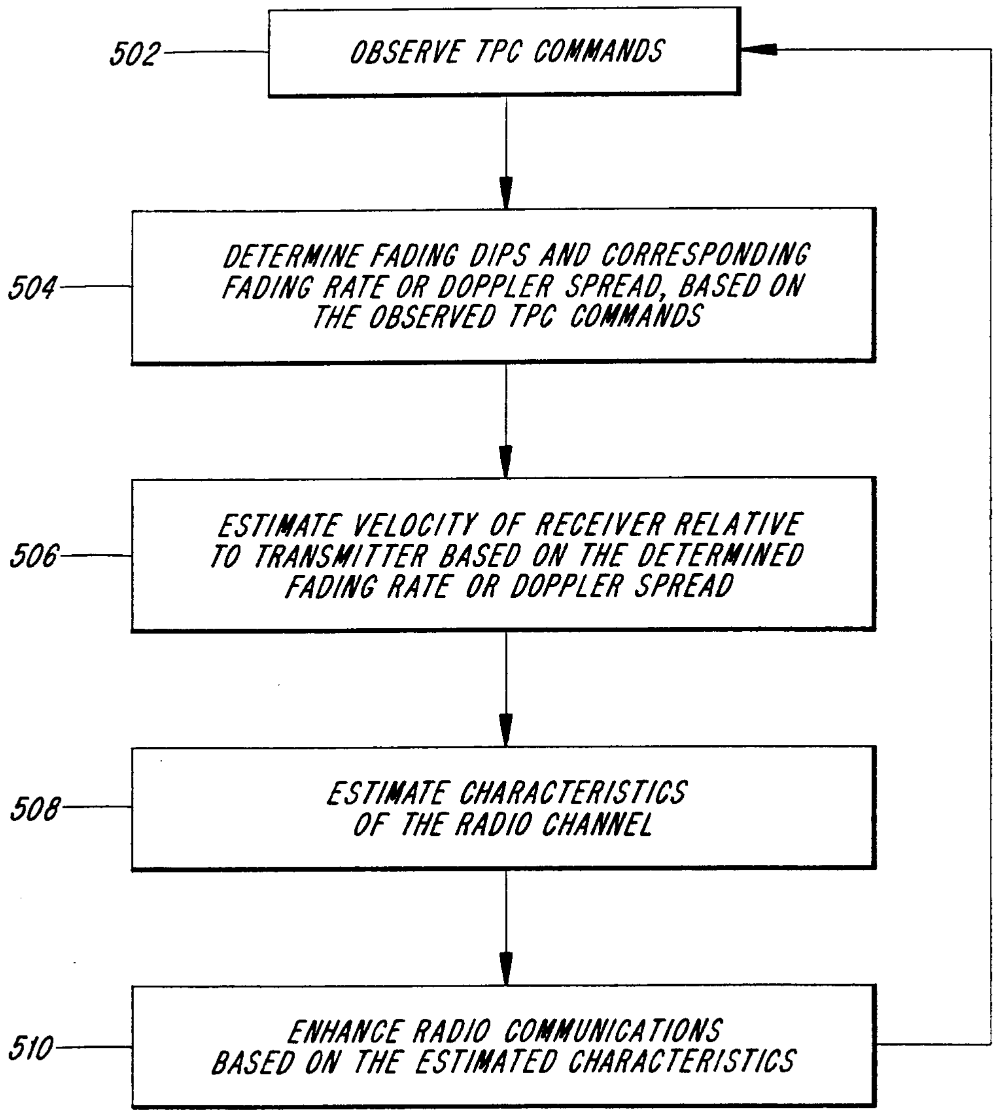

TRANSMITTER SIGNAL TRANSMISSION POWER
u d u d u u u u d u u u d u d d d d d d u d u d u
TPC COMMANDS
A
STEADY STATE
B
POWER INCREASE
C
POWER DECREASE
D
STEADY STATE
TIME

Fig. 5


502
OBSERVE TPC COMMANDS
504
DETERMINE FADING DIPS AND CORRESPONDING FADING RATE OR DOPPLER SPREAD, BASED ON THE OBSERVED TPC COMMANDS
506
ESTIMATE VELOCITY OF RECEIVER RELATIVE TO TRANSMITTER BASED ON THE DETERMINED FADING RATE OR DOPPLER SPREAD
508
ESTIMATE CHARACTERISTICS OF THE RADIO CHANNEL
510
ENHANCE RADIO COMMUNICATIONS BASED ON THE ESTIMATED CHARACTERISTICS

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/11188

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B17/00 G01S11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 99 12275 A (MOTOROLA INC) 11 March 1999 (1999-03-11) abstract page 8, line 16 -page 9, line 20 page 10, line 20 -page 11, line 5 ---	1-10
A	WO 98 59515 A (TELIA AB PUBL ;ANDERSIN MICHAEL (SE)) 30 December 1998 (1998-12-30) abstract page 7, line 14 - line 32 page 1, line 15 - line 21 page 2, line 31 -page 3, line 20 page 5, line 23 - line 30 --- -/--	1-10

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 March 2001	27/03/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lustrini, D

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INTERNATIONAL SEARCH REPORT

Interr nal Application No
PCT/EP 00/11188

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 13, 30 November 1999 (1999-11-30) & JP 11 220774 A (FUJITSU LTD), 10 August 1999 (1999-08-10) abstract ---	1,9
A	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 09, 30 July 1999 (1999-07-30) & JP 11 112420 A (OKI ELECTRIC IND CO LTD), 23 April 1999 (1999-04-23) abstract -----	1,9

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 00/11188

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